FUEL EFFICIENCY
BOOKLET 12

Energy management and
good lighting practices

ENERGY EFFICIENCY

**BEST PRACTICE
PROGRAMME**

The views and judgements expressed in this Fuel Efficiency Booklet are not necessarily those of the Department of the Environment, ETSU or BRECSU.

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INTRODUCTION

1 INTRODUCTION

The aim of this booklet is to give energy managers guidance on good lighting practice and the effective use of energy.

Proper standards of lighting are essential for safety, comfort and productivity, and it is hoped that the reader will use this booklet as a means of recognising opportunities for cost reduction, whilst at the same time achieving or maintaining the recognised lighting standards.

It is recommended that expert advice should be sought either from the electricity supply industry, the manufacturers of lighting equipment or consultants before any scheme of replacement or improvement of lighting is begun.

Readers are advised to consult manufacturers for the most up to date information in respect of product performance and interchangeability of lamps and circuit components, in view of the rapid rate of development in the lighting industry.

2 LIGHTING
- A GENERAL BACKGROUND

How much light do we need?

In the last 50 years a great deal of work has been done all over the world by ophthalmologists, government departments, universities, professional bodies such as the Lighting Division of the Chartered Institution of Building Services Engineers (CIBSE) and the lighting industry itself to determine fundamental visual requirements.

This work forms the basis of the CIBSE Code for interior lighting. The Code is widely known all over the world and its recommendations form the basis of most present day lighting practices in the United Kingdom. It not only lists the recommended values of illumination (illuminance) for a very wide range of specific tasks, but takes into account the effects of direct glare from the lighting fittings (luminaires) and other requirements for good lighting conditions.

Standard recommendations

The illuminances recommended in the Code reflect current good practice. They are not in themselves the sole criteria of good lighting: other factors such as visual comfort, the colour of the light and the 'atmosphere' of an installation must also be taken into account. The recommended illuminances do, however, provide a foundation on which to base lighting design.

Typical tasks and illuminances will give you an idea of the values recommended for tasks of varying degrees of visual complexity (see Table 1).

Use of daylight

In some situations, notably in shops, museums and areas where the directional quality of the lighting and illuminance must be strictly controlled, it may be necessary to exclude daylight, but the majority of people like natural light and a view out. Adequate daylighting can only be provided for a limited distance from windows or roof lights and will only be available for part of the working day. For this reason, correctly controlled artificial lighting must always be provided.

The benefit of natural lighting must not be ignored, however, and advantage should be taken of it where possible. The level of natural lighting does vary due to weather, season and

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time of day. Supplementary artificial light is normally required to maintain adequate lighting levels. These should be controlled to maintain a reasonably constant level of illumination in the work place.

Large areas of uncurtained glass may present problems; at night they will act as shiny black walls and cause discomfort; during the day they may well prove uneconomical because of high solar gain or heat loss. The use of modern glazing technology or outside shades will greatly reduce this problem and also reduce visual discomfort.

Appearance

A room in which all the light is concentrated on a horizontal working plane, and little or no light is allowed to fall on walls or ceilings, is likely to have a depressing atmosphere. In rooms of up to 25m² the feeling of claustrophobia can be mitigated by using light coloured walls, but in very large areas of 100m² or more, where the field of view is extensive, it is more effective to let some light reach the ceiling. The reflectors of most industrial luminaires are slotted in order to allow a small proportion of upward light to relieve this 'tunnel' effect.

Generally, increasing emphasis is being placed on the need to achieve not only effective lighting conditions for visual performance, but also attractive visual environments.

Effect of age on workers

As we get older, the greater difficulty experienced in seeing fine details can be partially corrected by the use of spectacles. Increasing the illumination helps, but it is seldom possible to predict the proportion of people of any age group in a given working environment. This is not taken into account in the recommended illuminances in Table 1, which assume an average age of 40-50 years. Information on providing an allowance for age is given in the CIBSE code.

Health and Safety

Good lighting is seen to be a contribution to health and safety at work whether it be natural or artificial. The Health and Safety Executive have produced a guide - HS/G 38 *Lighting at Work* - aimed at employers, safety personnel, designers and those who install and maintain lighting installations. The guide is mainly concerned with artificial lighting and how it affects the safety, health and welfare of people at work. It is not concerned with optimising performance or comfort.

The guide does not give recommendations for lighting to cover specific tasks in the work place and refers to the publications of the CIBSE.

3   GLARE

Direct glare

Direct glare from light sources and reflected glare from other surfaces in the field of view can often make seeing uncomfortable (discomfort glare), or it can reduce visibility (sometimes to a dangerous degree). It can, of course, produce both effects at the same time. Glare is not confined to electric (artificial) lighting conditions. Severe glare can be caused by badly positioned windows, and most people experience both direct and reflected glare out of doors, e.g. when driving towards the sun or looking across water.

Fortunately, direct glare from electric

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Maintained Illuminance (lux)	Characteristics of the Activity/Interior	Representative Activities/Interiors
Table 1 Examples of activities/interiors appropriate for each maintained illuminance		
50	Interiors rarely visited with visual tasks confined to movement and casual seeing without perception of detail.	Cable tunnels, indoor storage tanks, walkways.
100	Interiors occasionally visited with visual tasks confined to movement and casual seeing calling for only limited perception of detail.	Corridors, changing rooms, bulk stores, auditoria.
150	Interiors visited occasionally or with visual tasks requiring some perception of detail or involving some risk to people, plant or product.	Loading bays, medical stores, plant rooms.
200	Continuously occupied interiors or with visual tasks not requiring any perception of detail.	Monitoring automatic processes in manufacture, casting concrete, turbine halls, dining rooms, foyers and entrances.
300	Continuously occupied interiors, visual tasks moderately easy, i.e. large details >10 min arc and/or high contrast.	Packing goods, rough core making in foundries, rough sawing, libraries, sports and assembly halls.
500	Visual tasks moderately difficult, i.e. details to be seen are of moderate size (5-10 min arc) and may be of low contrast. Also colour judgements may be required.	General offices, engine assembly, painting and spraying, laboratories and retail shops.
750	Visual tasks difficult, i.e. details to be seen are small (3-5 min arc) and of low contrasts; also good colour judgements may be required.	Drawing offices, ceramic decoration, meat inspection.
1,000	Visual tasks very difficult, i.e. details to be seen are very small (2-3 min arc) and can be of very low contrast. Also accurate colour judgements may be required.	Electronic component assembly, gauge and tool rooms, retouching paintwork.
1,500	Visual tasks extremely difficult, i.e. details to be seen extremely small (1-2 min arc) and of low contrast. Visual aids may be of advantage.	Inspection of graphic reproduction, hand tailoring, fine die sinking.
2,000	Visual tasks exceptionally difficult, i.e. details to be seen exceptionally small (<1 min arc) with very low contrasts. Visual aids will be of advantage.	Assembly of minute mechanisms, finished fabric inspection.

1 minute of arc is 1/60 of a degree. This is the angle of which the tangent is given by the dimension of the task detail to be seen by the viewing distance

GLARE

lighting can usually be avoided. The contrast between a light source and its surroundings can be reduced by various methods, e.g. by reducing the surface brightness (luminance) of the luminaire by means of controlling media such as baffles, and by allowing more light to fall on walls and ceilings.

Reflected glare

Reflected glare is more difficult to overcome and is a common fault in offices and situations where glossy, light-coloured objects are in the field of view. Typical examples of reflected glare are:

- drawing offices where pencil lines become invisible because reflected light raises their brightness to that of the surrounding paper;
- reflected images of luminaires in the screens of visual display terminals.

In these and other similar situations, the reflected glare problem can be overcome, or minimised to an acceptable level, by suitable positioning of the luminaires relative to the task and, in some instances, by the use of luminaires having a more suitable light distribution. (For general advice see Building Research Establishment (BRE) Digest 256 - *Office Lighting for Good Visual Task Conditions* - and for Visual Display Terminal (VDT) areas see CIBSE Lighting Guide LG3 - *Areas for Visual Display Terminals*).

Reflected glare significantly reduces the ability to see the visual task, thereby reducing productivity. Such problems are not always easy to solve, and it is usually best to seek professional advice.

Direct glare from electric lighting equipment can cause considerable discomfort, depending upon the type of work being carried out. The CIBSE Code recommends limiting levels of discomfort glare. Limiting glare indices for tasks and various situations are given in the Code and should not be exceeded.

4   LIGHTING AND ENERGY

Lighting accounts for some 15% of electricity consumption in the United Kingdom. In commercial offices and retailing, lighting is frequently the major part of the electricity cost.

The UK spends well in excess of £2,000 million a year on electricity for lighting and energy efficiency could certainly cut the bill by some £400 million.

The success of any programme to reduce energy use and total costs incurred depends on identification of the individual cost factors.

An ordinary 240 volt 100 watt tungsten filament lamp may cost around 50p to buy. The cost of electricity used during its 1,000 hour average life would be £5.50 (at 5.5 p/kWh).

Evaluation of the cost factors in lighting provision would normally include all cost elements:

Cost of lighting equipment
Installation cost -
Labour and materials   } Capital costs
Replacement lamp costs

Maintenance and cleaning
costs   } Operating Costs
Electricity costs

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It is essential to assess the true cost of a lighting system when considering its performance. This is not simply a matter of comparing the individual costs of lamps and luminaires. It is easy to overlook some of the other factors involved, such as the reduced numbers of luminaires, the use of controls, the reflectance of surfaces, the amount of glazing and the pattern of use of premises. It is also useful to assess the respective advantages or disadvantages of alternative capital costs and payback periods.

In order to simplify this task, a sample cost analysis sheet is given in Appendix 1 on which data may be recorded to enable a reasonable comparison to be made between any proposed systems.

The main factors influencing the energy use in an installation for a given lighting standard are:

1. Lamp efficacy (light output of the lamp type used per watt of electrical power consumed).
2. Luminaire (lighting fitting) performance.
3. The lighting scheme design.
4. The decor and furnishing.
5. Maintenance standards.
6. Proper use of switching and controls.

1 to 5 above relate to the fundamental efficiency of the installation, while 6 is concerned with the management and use of the installation in relation to user requirements and occupancy patterns for the areas concerned.

Choice of lamp type

There are two main types of electric lamp - tungsten filament and discharge (which includes fluorescent tubes). Luminous efficacy (efficiency) is defined in lumens per watt, and for comparison purposes account should be taken of the control circuit losses of fluorescent and discharge lamps. Ranges of efficiency are shown pictorially in Fig 1.

When designing a new installation, the lamp type selected should have as high an efficacy as possible, with characteristics that suit the requirements of the installation - i.e. colour properties (appearance and rendering), life or service period, and so on.

For an existing installation, a change to a more efficient lamp type will reduce energy consumption and therefore cost. Some such changes involve little or no capital expenditure - others may require the addition, or change, of control gear, or a change of luminaire type and/or position.

Fluorescent lamps (like other discharge lamps) need some form of starting device (starters) and a means of controlling the lamp current once started (ballast). A capacitor is also normally connected to provide power factor correction and reduce the current drawn from the mains for a given wattage.

Control gear (starters and ballasts) come in a variety of forms. The most simple uses a starter and choke (iron cored inductor). The starter switch may be a plug-in glow starter (which should be replaced at every second or third lamp change) or an electronic starter. Special low-loss chokes can be obtained with greater copper content to improve the efficiency of switch and choke starters. These are heavier and bulkier than standard chokes and are more expensive.

All-electronic and part-electronic ballasts are similar to the ballasts used in emergency lighting equipment. They are more efficient than conventional circuits and operate suitable lamps

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Fig 1 Luminous efficacy and light output
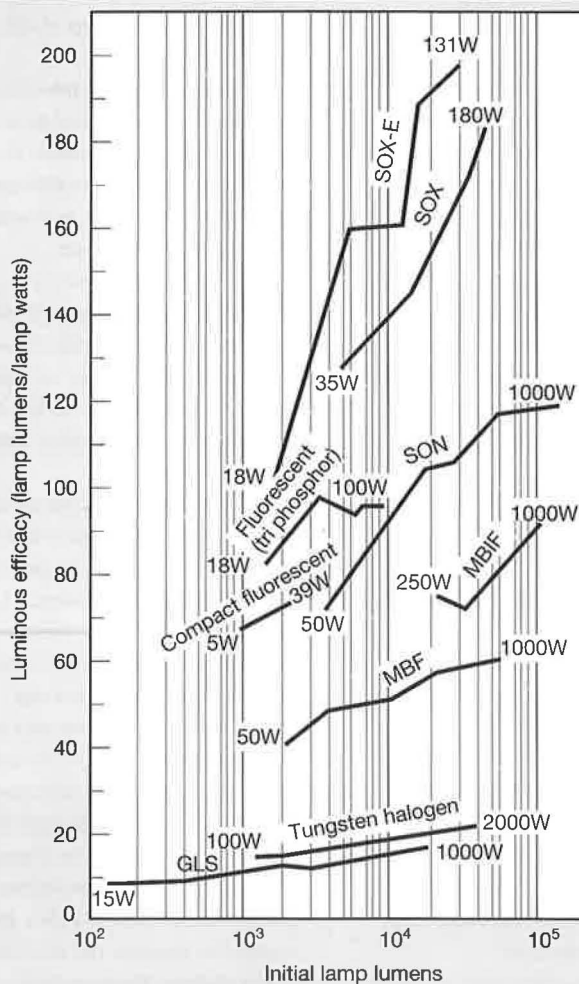
Key:
GLS	Tungsten filament
MBF	High pressure mercury discharge (fluorescent)
MBIF	High pressure mercury discharge (metal halide)
SON	High presure sodium discharge
SOX	Low presure sodium discharge

THE LUMINAIRE AND SCHEME DESIGN

more efficiently, but this efficiency is achieved at a greater cost, which may not be justified.

High frequency (HF) and HF regulating (HFR) gear incorporate ballasts to convert 50 Hz into 28,000 Hz. These have certain advantages over normal 50 Hz control gear, namely increased efficiency, reduced losses compared with switchstart and consequently lower running costs. Other advantages are that mains flicker, hum and the stroboscopic effect (causing misleading impressions of rotating machinery speed) are eliminated. HFR ballasts also allow the output to be varied between 10% and 100%.

Compact fluorescent lamps are available in various configurations; some types have integral control gear, while others require a separate ballast. Compact size is achieved by folding the discharge tube and require about one quarter of the power of GLS filament lamps of similar output. Life is some five times that of the GLS lamp. The compact lamp finds a wide range of application as a replacement for or an alternative to the GLS filament lamp.

The rate of lamp development is rapid. It is therefore important to refer to manufacturers' literature for up-to-date information on the ranges/types available, performance data and interchangeability of lamps.

5 THE LUMINAIRE AND SCHEME DESIGN
The main functions of luminaires are to control the light emitted by the lamp(s), to support and protect the lamps, provide the electrical connections to the supply and to control and direct the light emitted by the lamps.

A luminaire should comply with the mechanical, thermal and electrical requirements of British and related (IEC and CEE1) overseas standards, and must comply with the relevant requirements of the *Electricity at Work Regulations* (SI 1989 635). Lighting equipment should be easy to install and maintain, and diffusers, reflectors and refractors should be able to withstand the normal handling involved in removal for routine cleaning and relamping.

The British Standard for Luminaires, BS 4533 (EN 60598), has been revised to align with requirements of the latest IEC Specification 598. BS Safety mark indicates compliance with safety standard BS 4533 (IEC 598). The Standard details stringent requirements and tests to check the electrical, thermal and mechanical safety of luminaires. Class 0 luminaires, i.e. those not having provision for earthing or supplementary insulation, are excluded from the British Standard.

Protection against electric shock shall be provided either by earthing (Class 1 luminaires) or by doubling insulation (Class 11 luminaires).

Luminaires may be classified according to the protection they afford against the ingress of moisture, solid bodies and dust, and against contact with live or moving parts. These are based on the IP (International Protection) numbering system defined in BS 4533, Pt 101: 1990. The 16th edition of the IEE wiring regulations calls for equipment to comply with the appropriate British Standard (in this case BS 4533).

The efficiency of a lamp/luminaire combination when used to provide general lighting in interiors can be expressed by the utilisation factor, which is derived from:

THE LUMINAIRE AND SCHEME DESIGN

$$\frac{\text{luminous flux at the working plane}}{\text{luminous flux emitted by the lamp.}}$$

Other design criteria for the installation, particularly glare, must of course be taken into account.

Task lighting

Localised or task lighting schemes normally consume less energy than general lighting systems, unless a high proportion of the area is occupied by work areas.

Considerable care must be taken to co-ordinate the lighting layout to task positions and orientation. Changes in work layout can seriously impair a localised system but this problem can be overcome by suitably positioned uplighters. It is essential that illuminance of other areas should not be less than one-third of the illuminance on the task areas.

Uplighters

Uplighters are luminaires which direct most of the light output onto the ceiling and upper walls in order to illuminate the working plane by reflection. The efficiency of the system compared with 'downlighting' is reduced depending on ceiling surface reflection factors, but uplighters can provide a high degree of flexibility and a pleasing atmosphere.

Lighting for visual display terminals

Lighting for areas in which visual display terminals (VDTs) are installed calls for considerable care in avoiding glare and troublesome reflections.

Recent legislation has important implications for the lighting of areas in which visual display screens are used. The *Health and Safety (Display Screen Equipment) Regulations* 1992 must be consulted. These regulations implement the 1990 EC directive 90/270/EEC and are mandatory for all new workstation installations from the beginning of 1993. Employers are required to ensure that workstations, whether or not they are new, which are put into service after this date comply with the relevant part of the regulations. Workstations already in service should comply by 31 December 1996.

Further guidance is given in the CIBSE Lighting Guide LG3 - *Areas for Visual Display Terminals*. The guide is aimed to give designers, employers and the computer user more guidance and information on the subject of lighting these areas, and on resolving problems that may exist where VDTs are used.

Effect of decoration and furnishings

Attention has already been drawn to the absorption of light at night by large, uncurtained areas of window. All surfaces absorb light to some degree, and the lower their reflectance, the more they absorb. It follows, therefore, that light-coloured surfaces are more efficient reflectors, but should be regularly painted, washed or repapered in order to ensure the economical use of light. Inter-reflection from coloured surfaces of a room can affect both the quantity and colour of the light at working surfaces.

Maintenance

In the past there was a tendency to 'fit and forget' and only replace lamps when they failed. One consequence of this was that illuminance levels would fall to the extent that safety,

THE LUMINAIRE AND SCHEME DESIGN

productivity or turnover would be seriously affected. Thus the importance of regular maintenance of all forms of lighting equipment cannot be stressed too strongly.

Loss of daylight through dirty windows should not be tolerated, but it must not be forgotten that luminaires also collect dust and dirt, resulting in a fall in light output. With most electric lamps light output falls gradually throughout life, but by far the greatest loss of light can arise from the accumulation of dust and dirt on the lamps themselves or on the reflecting or other light controlling surface of the luminaires, and also on the ceilings, walls and other reflecting surfaces within the room. Even in a clean atmosphere, such as an office, this can reduce light output by at least 20%, and in foundries and some heavy engineering works the reduction will be as high as 40% or more. Additionally, the accumulation of dust on the upper surfaces of the luminaire can lead to overheating and consequent deterioration of wiring and control gear.

A regular cleaning schedule should be established and, although it should occur more frequently, it can be timed to coincide with the group replacement of lamps. Cleaning cycles that do not coincide with bulk replacement are a good opportunity to deal with spot failures. The replacement of lamps as and when they fail individually can be an expensive process; wasteful of the electrician's and storekeeper's time and often of those working in the vicinity.

Lamp service period
When applied to electric lamps, the word 'life' has two distinct meanings:

- the time after which the lamp ceases to operate;
- the time after which the light output is reduced, by normal deterioration processes, to such a low level that it is more economic to replace the lamp, even though it is still operating electrically. This is the 'economic service period'.

Filament lamps fall under the first definition of 'life'. The rated life of common types under specified conditions is defined in international standards and is accepted as a practical life-efficacy compromise.

Discharge and fluorescent lamps fall under the second definition. The life of discharge lamps is a complicated subject and there are no international standards on the meaning of 'life'. Present day discharge and fluorescent lamps will survive for many thousands of hours, but during that time the light output steadily depreciates - if the lamps are operated until they fail electrically, the light output could be half or less of what it was initially. In practice, discharge and fluorescent lamps should be changed at the most economic time for the particular installation.

Planned maintenance
When a lighting scheme is designed, the designer must take into account four main factors:

- the lamp lumen maintenance factor (the deterioration of lamp output with time);
- the lamp survival factor (the deterioration of lamp life due to frequent switching of the lamp);
- the luminaire maintenance factor (the degree of dirtiness of the luminaire);

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Table 2 Case study with and without planned maintenance			
Designed electrical load	**1**	**2**	**3**
	100%	90%	85%
Maintenance	Very little. Lamps replaced on failure, irregular cleaning (if any)	Planned e.g. Clean after 3,000 hours; clean & relamp after 6,000 hours	Planned e.g. Clean after 2,000 hours; clean & relamp after 4,000 hours
Realised illumination level: Initial	100	90	85
at 2,000 hours	82	73	69⇒80 after cleaning
at 3,000 hours		Clean	
at 4,000 hours	67	74	65⇒85 after cleaning & relamping
at 6,000 hours	53	62⇒90 after cleaning & relamping	69⇒80 after cleaning
at 8,000 hours	44	73	65⇒85 after cleaning & relamping
Mean average	72	76	75
Number of lamp changes	1+	2	3
Running cost comparison (electricity, cleaning & lamps)	100%	94%	93.5%
Savings (mantenance costs included)	-	6%	6.5%

Notes: 1. Deterioration in room surfaces not taken into account.

2. Based on a reflector or louvred reflector type luminaire with fluorescent lamp.

3. Typical applications - supermarkets, department stores, offices and light industry.

THE LUMINAIRE AND SCHEME DESIGN

- the frequency of cleaning and the room surface maintenance factor (the degree of loss due to dirt on walls and ceilings).

The combination of these factors is called the maintenance factor. Thus if the designer expects the system to deteriorate by, say, 20% over a certain period of time, a maintenance factor of 20% should be used in calculations to ensure that the designed lighting levels will be achieved at the end of that period. The illuminance level, when installed, will therefore need to be 125% of the design average. What does this mean for the energy manager? It means that because little maintenance is envisaged, capital and running costs will be 25% higher than they need be. With planned maintenance covering lamp cleaning and replacement, some of these additional costs could be saved, as the designer would be able to use a lower maintenance factor in calculations. The example in illustrates one of the benefits of planned maintenance (Table 2).

Planned lamp replacement

In all but the smallest installations it is sensible to replace lamps as a group at planned intervals. Similarly, when switch start fluorescent luminaires are being maintained, it is usually economical to replace the starter switches in groups every two lamp lives. It may be economical to replace glowstart with electronic starters which do not need such frequent replacement.

The optimum replacement period for lamps depends on the energy and labour costs of a particular installation. A common rule is that lamps should be group replaced when the cost of wasted energy has become as high as the cost of lamp replacement. A further limit is that lamps should be replaced before their output has depreciated by about 30% below the initial value. Manufacturers should be consulted to obtain the light depreciation curve for the particular lamp used.

6 SWITCHING AND CONTROLS

The purpose of controls is to see that lighting is provided:
- in the right amount;
- in the right place;
- for the required time.

Even with efficient lamps, luminaires etc, the energy used for lighting can be wasted in several different ways (see BRE Digest 232 - *Energy conservation in artificial lighting*). Careful monitoring studies show that, in general, people will usually turn lighting on only when they need it, but cannot be relied upon to turn it off when daylight would provide adequate conditions or when rooms are to be unoccupied. Exhortation can be helpful in the short term, but the ideal solution is to provide manual switch on and some form of control for switching off. A further source of unnecessary use results from the common practice of controlling large areas of lighting with small numbers of switches, or by confusing switch layouts such that individual requirements can only be met by turning on many luminaires. Controls are a very effective way of reducing lighting costs, but before incurring significant capital costs, it is suggested that the occupancy pattern and occupancy behaviour should be studied. This will enable the most cost effective system of control to be installed. Methods of lighting control are

SWITCHING AND CONTROLS

evaluated in BRE Digest 272 - *Lighting controls and daylight use.*

Manual controls

Switching arrangements should at least permit individual rows of luminaires parallel to window walls to be controlled separately. Controls (both mechanical and electronic) are available to permit individual luminaires in a large installation to be switched by the occupants most affected. Switches should be as near as possible to the luminaires which they control. One simple method which has been used effectively is the pull cord, operating ceiling switches adjacent to each luminaire. Electronic controls (ultrasonic or infra-red) can be placed on or near the occupants' desks to give them control of one or more luminaires. A master control of this type avoids any necessity for wiring to switches on walls, but does require specific control units to be fitted to luminaires.

Sensing devices are generally not suitable in factories, their best applications being sports halls, warehouses, office cleaning and other places where occupancy can be intermittent.

Automatic controls

Photoelectric controls

Photoelectric control of lighting can ensure that the lighting will be turned off when daylight alone provides the required illuminance. For example, a photoelectric sensor could respond to the exterior illuminance, and be set to operate at that exterior illuminance which provides the design illuminance in the work place.

Gradual 'top-up' (or dimming) control is preferable to simple on-off switching. Occupants do not dislike it and it saves more energy than switch control. It is possible to control the light output of fluorescent lamps to provide sufficient illuminance to top-up daylight when it fails to

Fig 2 Control of more than one row of lights

Off   40%   70%

Sunlight
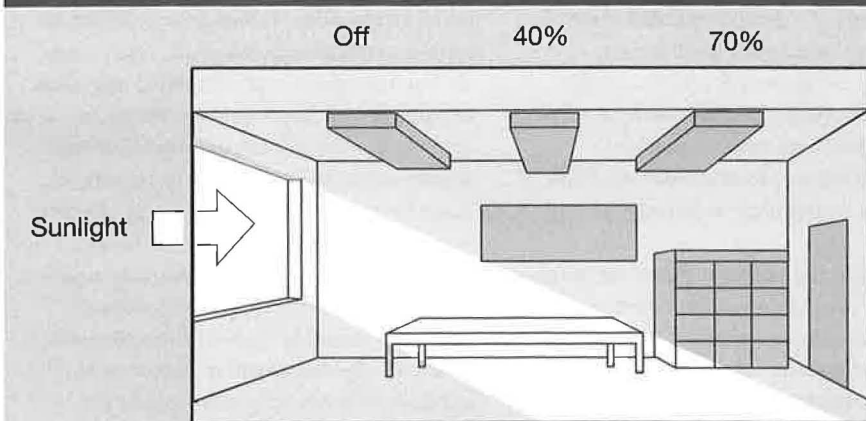
SWITCHING AND CONTROLS

reach the design level of the artificial lighting by itself. Such a system will use less energy than one which switches the lighting on fully for the whole time that the daylight is below the design illuminance.

With fairly deep interiors having two or more rows of lights running parallel with the window walls (or walls), it may be advantageous to use a separate controller for each row (see Fig 2). If the control is of the on-off type, only the row nearest the window should be operated in this way to ensure use acceptability, although careful design with multi-lamp luminaries may be acceptable. Potential energy savings can be large (up to 50% of uncontrolled use has been claimed), but evaluation of particular installations is required to determine their cost effectiveness. In general, top-up or dimming control is more expensive than on-off switching, but it saves more energy and is more unobtrusive.

Time controls

If the occupation of a building effectively ceases at a fixed hour every working day, it may be worth installing a time switch so that most of the lighting is switched off soon after this time. Arrangements may need to be made, however, for security lighting and for individuals working late, to override part of the switching with subsequent automatic switching off and override cycles to avoid accidental leaving on. The building cleaning routine may also need special arrangements. Sequential control of lighting may be appropriate when a cleaning gang moves

from floor to floor. Arrangements must be made, however, to ensure that no one ever has to enter an unlighted space or be in a space where all the lighting is out of their control.

Mixed controls systems

Switch control can produce considerable energy saving. A time control system, for example, which switches all selected lights off at a fixed period in the day, but with personal local override (switch on), can have a payback of one and a half to two years, as demonstrated in projects using time switching, photoelectric and localised controls under the Energy Efficiency Demonstration Scheme run by the former Department of Energy[2]. If a time control system is fitted at the time of refurbishment, payback can be one year or less. This general principle is well suited to multi-occupant spaces, such as group offices, but with care can be applied in schools, factories, warehouses and so on. Commercial systems exist which enable this principle to be followed, some of which also offer the further option of photoelectric switching - with occupant override - to promote greater savings. The use of remote switching (e.g. by infra-red transmitters, or ultrasonics), to fulfil the localised override facility is also possible.

BRE Digest 272- *Lighting controls and daylight use* - contains a decision chart on the selection of control strategy.

[2] *This scheme has been replaced by the Department of the Environment's Energy Efficiency Best Practice programme.*

AUDIT OF EXISTING INSTALLATIONS

7   AUDIT OF EXISTING INSTALLATIONS

■ **Date installed:**
Any installation that is more than 20 years old is probably due for rewiring. Luminaires that are over ten years old will probably have deteriorated and in many cases versions of higher efficiency will be available, making replacement a worthwhile investment.

■ **Check the illuminance:**
Readings should be taken with a light meter of known accuracy either at every working point, or at the centres of a regular grid pattern (which does not coincide with the luminaire spacing grid) throughout the area in the horizontal working plane. The average horizontal illuminance is the average of these readings. The variation in illumination over a task should not be excessive. The ratio of minimum luminance to average luminance over the task area should be more than 0.8. The lowest illuminance in the spaces should not be less than 30% of the average.
The average illuminance and the levels at individual workstations of the installation should be checked with those recommended in the CIBSE Code, and a decision should then be made as to the acceptability of the installation in respect of productivity, health, safety and morale.

■ **Light source and luminaire type:**
The reflectors are likely to have deteriorated with age and absorb a high percentage of the light. In warehouse/industrial units, consideration should be given to changing

both lamps and reflectors, using high pressure sodium, metal halide or high pressure sodium deluxe. In offices illuminated by tubular fluorescent lamps, discolouration of reflecting and diffusing surfaces of the luminaires may have occurred.
Replacement by new luminaires with more efficient lamps will result in energy savings, often with a higher illuminance. In general, reflector or prismatic control enables a given task illuminance to be provided with less energy than diffusers or bare lamps. In 'low bay' factories, SON and fluorescent lighting are both good choices. In factories where rotating machinery, such as lathes and drills are used, then high frequency fluorescent luminaires should be seriously considered.

■ **The state of decoration:**
The condition of the walls, ceilings and other surfaces within the building should also be considered at this stage. Redecorating using light shades will improve the reflectance of surfaces and make a significant contribution to improving the installation efficiency, but it must be maintained.

■ **Check the installation and wiring:**
In the case of old fluorescent or discharge lamp installations, apart from the deterioration due to dust and dirt, power factor capacitors may have become open circuit and, consequently, 'wattless' current will have increased, thereby increasing the power factor penalty under many tariffs.

AUDIT OF EXISTING INSTALLATIONS

■ **Check purchasing records:**
In many cases it will be useful to check purchasing records, to identify any regular purchases of obsolete or inefficient products. The regular annual purchase of GLS tungsten filament lamps perhaps indicates scope for conversion to compact fluorescent lamp types. Equally, purchase of BC capped fluorescent tubes or mercury discharge lamps (MBF) may be worth investigation.

■ **Installation efficiency check:**
As a management check on the efficiency of general commercial and industrial lighting:
a Measure the area in m^2
b Assess installed lighting load in watts. (Number of lamp points x lamp wattage; add 12% for control gear for fluorescent and discharge lamp installations.)
c Divide **b** by **a** to obtain installed load in W/m^2
d Measure average illuminance (Lux)
An installation with modern efficient equipment will require an installed load of approximately:
Industrial lighting =
2-3 W/m^2 for each 100 Lux illuminance
Commercial lighting =
2.5-3.5 W/m^2 for each 100 Lux illuminance
If your check shows an electrical load above these figures, then more detailed investigation is advised.
Note: This technique is suited to general industrial and commercial lighting - it is not appropriate for display and decorative installations.

■ **Check flexibility of switching control:**
Look at the occupancy pattern for the areas concerned. Is the flexibility of switching and control systems adequate to ensure that no waste occurs when areas are unoccupied? Is lighting off when sufficient daylight is available?

8 BIBLIOGRAPHY

Lighting
Building Research Establishment: BRE Digests. On sale from HMSO bookshops.

Chartered Institution of Building Services Engineers (CIBSE):
Code for interior lighting.
Lighting Guides for specific applications, e.g.. VDT, Industrial environment, etc.

A list and copies are available from:
CIBSE
222 Balham High Road
London SW12
Tel: 0181 675 5211.

Lighting Industry Federation (LIF) publish a series of Factfinders and a lighting design guide which provide information and guidance on lighting matters.

These include:
2   Dimming
3   Lamp guide
4   Lighting and energy
5   The benefits of certification
6   Energy Manager's Lighting Handbook

SOURCES OF FURTHER READING AND INFORMATION

Interior Lighting Design, 6th edition
A list and copies are available from:
The LIF
207 Balham High Road
London SW17 7BQ
Tel: 0181 675 5432

Energy use
CIBSE Energy Code Parts 1, 2, 3 and 4.

9   SOURCES OF FURTHER READING AND INFORMATION

■ *Energy Efficiency Best Practice publications:*
Copies of Energy Efficiency Best Practice
programme publications and other literature
applicable to energy efficiency in buildings are
available from:

Enquiries Bureau
BRECSU
Building Research Establishment
Garston
Watford
WD2 7JR
Tel: 01923 664258 Fax: 01923 664787

Information is also available through regional
Government Offices.

■ *The latest news in energy efficiency technology*
Energy Management is a free journal issued on
behalf of the Department of the Environment
and contains information on the latest
developments in energy efficiency, with details
of forthcoming events designed to promote their
implementation. It also contains information,
addresses and contacts for the regional
Government Offices.

Copies of *Energy Management* can be
obtained through:

Emap Maclaren Ltd
Maclaren House
19 Scarbrook Road
Croydon
Surrey
CR9 1QH

APPENDIX 1 COMPARATIVE LIGHTING COST ANALYSIS

COMPARATIVE LIGHTING COST ANALYSIS
Project:
Prepared for:
Report Number:

Luminaire Type	System A		System B	
Capital Costs:	Each	Total	Each	Total
1. Quantity of luminaires				
2. Luminaire cost £				
3. Number of wiring points				
4. Cost per point £				
5. Initial system cost including controls £				
6. Number and type of lamps				
7. Lamp cost £				
8. Initial system cost with lamps £				
9. Average illuminance in working place				
10. Capital cost per lux				
Annual Owning and Operating Costs	Each	Total	Each	Total
11. Quantity of luminaires				
12. Watts per luminaire (including control gear losses)				
13. kW load				
14. Hours in use per year				
15. kWh per year				
16. Annual energy cost £				
(a) maximum demand charge				
(b) units charge				
17. Nominal lamp life (hours)				
18. No. of lamps/luminaries				
19. No. of lamps replaced/year				
20. Cost of lamps/year				
21. Maintenance cost:				
(a) Lamp change £				
(b) Reflector cleaning £				
22. % Interest x initial system cost £				
23. Annual operating cost (16 + 20 + 21) £				
24. % Amortisation x initial system cost £				
25. Annual owning and operating cost (22 + 23 + 24) £				
26. Average illumination (illuminance)				
27. Owning and operating cost per lux £				
28. Installation efficiency W/m²/100 lux,				
Summary	£			
1. Initial cost of System A including lamps				
2. Initial cost of System B including lamps				
3. Initial cost saving (1) - (2)				
4. Annual owning and operating cost, System A				
5. Annual owning and operating cost, System B				
6. Annual owning and operating cost, saving (4) - (5) or (5) - (4)				
7. Total savings after an amortisation period of .... years for system ( )				

Note: A system may have low initial costs but high operating costs and may not necessarily be the cheapest in total costs

Titles in the Fuel Efficiency Booklet series are:

Fuel Efficiency booklets are part of the Energy Efficiency Best Practice programme, an initiative aimed at advancing and promoting ways of improving the efficiency with which energy is used in the UK.

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